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Box PATENT APPLICATION

Assistant Commissioner for Patents Re: New U.S. Patent Appln.
Washington, D.C. 20231 Our Ref: 3007/48504

Sir:

Transmitted herewith for filing is the patent application of:

Motoh ASAKURA, Kenji HOSAKI

entitled: **DISPLAY SYSTEM**

Enclosed are:

1. Specification, including 6 claims (24 pages).
2. 3 Sheets of Formal Drawings showing Figs. 1 - 3.
3. Declaration and Power of Attorney (unexecuted).
4. Certified copy of Priority Document JP 10-372523 filed in Japan on December 28, 1998, the priority of which is being claimed under 35 U.S.C. §119 and 37 C.F.R. §1.55.
5. Information Disclosure Statement with Form PTO-1449 and cited references (3).
6. The filing fee has been calculated as shown below:

Basic Fee		\$380/760 =	\$760.00
Total Claims	<u>6</u> - 20 =	<u> </u> x \$ 9/18 =	\$
Independent Claims	<u>3</u> - 3 =	<u> </u> x \$39/78 =	\$
Multiple Dependent Claim Presented		\$130/260 =	\$
Total Filing Fee			<u>\$760.00</u>

Respectfully submitted,

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JDE:dcb

DISPLAY SYSTEM

BACKGROUND OF THE INVENTION1. Field of the Invention

5 This invention relates to improvements in a display system for optically projecting a display light of information to be observed by a person from a liquid crystal display as a display device, and more particularly to the display system such as a head-up display system which is configured, for example, such that an
10 operator and the like can observe an image of driving information projected as the display light on a windshield glass or on a combiner provided on the windshield glass while looking a frontal view through the windshield glass in such a manner that the driving information is superimposed on the frontal view, in a vehicle or a
15 ship, or the like display system for architecture.

2. Description of the Prior Art

A variety of head-up display systems of an automotive vehicle have been hitherto proposed and put into practical use. A typical head-up display system is constituted by directly applying a
20 film functioning as a half mirror on a windshield glass, or by interposing the half mirror between two glass plates. However, with this head-up display system, reflection of light of an image is unavoidably made on the front-side or rear-side surface of the glass plate thereby forming a double image which is difficult to be
25 observed by a driver. In view of this, another types of the head-up display system have been proposed, in which light of the image is reflected from the surface of the glass plate without using the half mirror in order to avoid formation of the double image. One of these is configured by applying a so-called $\lambda/2$ film (for changing a
30 direction of polarization of light) on a transparent plate such as a glass plate, as disclosed in Japanese Patent Provisional Publication No. 2-141720. Another one is configured by bonding a transparent film having birefringence on a transparent plate, as disclosed in

Japanese Patent Provisional Publication No. 2-294615. A further one is configured by bonding a optical rotation layer formed of a crystalline high polymer on a transparent plate, as disclosed in Japanese Patent Provisional Publication No. 6-40271. Additionally, 5 some of the inventors of this application have proposed a display system including a combination of an optical rotation film, a light-transmittable reflection film and an antireflection film, as disclosed in a United States Patent Application No. 08/621379 entitled "Glass Arrangement".

10 The above display systems usually employs a fluorescent display tube or a liquid crystal display as the displaying device for generating the display light of information to be incident on the glass plate.

15 However, widely used liquid crystal displays except for some small-sized televisions using a liquid crystal display are so set that the axis (plane) of polarization is generally oblique relative to a vertical axis and a horizontal axis of the image plane of the liquid crystal display, i.e., generally along a diagonal line of the image plane in order to keep a bilateral symmetry of angle of visibility. 20 Accordingly, it is impossible to prevent formation of the double image by using the conventional optical rotation film capable of rotating the plane of polarization about 90°. In order to prevent formation of the double image, it is required to use a small-sized liquid crystal display having an axis (plane) of polarization vertical 25 or horizontal in the image plane of the liquid crystal display, or to use a specially prepared liquid crystal display whose axis of polarization is adjusted only corresponding to the display system.

SUMMARY OF THE INVENTION

BRIEF SUMMARY OF THE INVENTION

30 It is an object of the present invention to provide an improved display system which can effectively overcome drawbacks encountered in conventional display systems such as a head-up display system.

Another object of the present invention is to provide an improved display system which is simple in construction and can effectively prevent formation of a double image to be recognized by an operator, even by using a usual liquid crystal display whose axis 5 (plane) of polarization is inclined about 45° relative to a vertical axis on the image plane of the liquid crystal display.

An aspect of the present invention resides in a display system, comprising a transparent plate. A liquid crystal display is provided for generating a display light of information. The display 10 light has a plane of polarization inclined by an angle of about 45° relative to a vertical axis of an image plane of the liquid crystal display. A first optical rotation layer is disposed to a first surface of the transparent plate. The optical rotation layer is adapted to receive the display light from the liquid crystal display and to 15 optically rotate the plane of polarization of the display light by an angle of about 90°. A second optical rotation layer is disposed between the image plane of the liquid crystal display and a second surface of the transparent plate. The optical rotation layer is adapted to optically rotate the plane of polarization of the display 20 light from liquid crystal display by an angle of about 45° and to allow S-polarized light to outgo toward the transparent plate at Brewster's an. The S-polarized light is reflected on a side of the second surface of the transparent plate to be directed toward an eye of an operator.

Another aspect of the present invention resides in a 25 display system comprising a transparent plate. A liquid crystal display is provided for generating a display light of information. The display light has a plane of polarization inclined by an angle of about 45° relative to a vertical axis of an image plane of the liquid crystal display. A first optical rotation layer is disposed to a second surface 30 of the transparent plate. The optical rotation layer is adapted to optically rotate the plane of polarization of the display light incident thereon by an angle of about 90°. The display light from the first optical rotation layer is reflected on the second surface of the

transparent plate and directed toward an eye of an operator. Additionally, a second optical rotation layer is disposed between the image plane of the liquid crystal display and a second surface of the transparent plate. The second optical rotation layer is adapted to 5 optically rotate the plane of polarization of the display light from liquid crystal display by an angle of about 45° and to allow P-polarized light to outgo toward the first optical rotation layer at Brewster's angle.

A further aspect of the present invention resides in a 10 display system comprising a transparent plate. A liquid crystal display is provided for generating a display light of information. The display light has a plane of polarization inclined by an angle of about 45° relative to a vertical axis of an image plane of the liquid crystal display. The display light is incident on a second surface of the 15 transparent plate at Brewster's angle and reflected on a side of the second surface of transparent plate to be directed to an eye of an operator. An optical rotation layer is disposed to a first surface of the transparent plate. The optical rotation layer is adapted to receive the display light from the liquid crystal display and to 20 optically rotate the plane of polarization of the display light from the liquid crystal display by an angle of about 45° and to allow P-polarized light to outgo therefrom.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, like reference numerals designate like 25 parts and elements throughout all figures, in which:

Fig. 1 is a fragmentary schematic sectional view of a first embodiment of a display system according to the present invention;

Fig. 2 is a fragmentary schematic sectional view of a second embodiment of the display system according to the present 30 invention; and

Fig. 3 is a fragmentary schematic sectional view of a third embodiment of the display system according to the present invention.

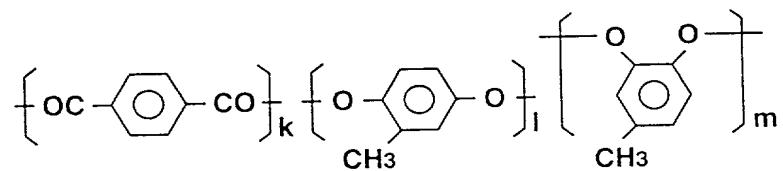
DETAILED DESCRIPTION OF THE INVENTION

Referring now to Fig. 1 of the drawings, a first embodiment of a display system according to the present invention is illustrated by the reference character S. The display system S of this 5 embodiment is a head-up display system and constituted by incorporating optical rotation (polarization-direction changing) layer or films 2, 7. The optical rotation layers 2, 7 are adapted to change the direction of polarization of light to be incident thereon, i.e., to rotate a plane of polarization of light to be incident thereon. 10 The optical rotation layers 2, 7 in this embodiment are formed of a liquid crystal polymer which is in twisted nematic orientation under a liquid crystal condition and is in a glassy state at a temperature lower than liquid crystal transition point thereof.

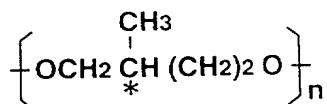
The optical rotation (polarization-direction changing) 15 layers 2, 7 are formed as follows: The liquid crystal polymer is coated on a transparent substrate (substrate film) such as a plastic film formed of, for example, polyethylene terephthalate (PET). Then a shearing force is applied to the liquid crystal polymer, and thereafter the liquid crystal polymer is subjected to heat-treatment 20 and then cooling so that a liquid crystal orientation is fixed. Thus, the optical rotation layer 2 is formed on the surface of the substrate film.

In this embodiment, the liquid crystal polymer is one represented by the following chemical formula:

25



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where $k = 1 + m + n$; $k/n = 99.9/0.1$ to $90/10$, preferably $99.7/0.3$ to $95/5$; $1/m = 5/95$ to $95/5$; and a symbol * in the formula represents optically active carbon.

The above liquid crystal polymer can be formed into the
5 first and second optical rotation layers 2, 7 by controlling a content
of optically active unit components in the liquid crystal polymer, a
thickness of the liquid crystal polymer, conditions of the heat-
treatment for causing the liquid crystal polymer to exhibit a
10 crystalline characteristics, and the like. The first optical rotation
layers can rotate a plane of polarization of light to be incident
thereon by an angle of about 90° . The second optical rotation layer
can rotate a plane of polarization of light to be incident thereon by an
angle of about 45° .

The thus formed optical rotation layer 2 is removed from
15 the substrate film and then bonded to the inboard surface of an
outboard-side glass plate (transparent plate) 1A forming part of a
front windshield glass W, with a tape-like adhesive (not shown).

A light-transmittable reflection film or layer 3 is formed at
a part of the inboard surface of an inboard-side glass plate
20 (transparent plate) 1B forming part of the front windshield glass W,
under deposition of a metal thin film formed of Al, Au, Ag, Cu or the
like. deposition of the .

Thereafter, the inboard-side glass plate 1B is temporarily
bonded at its outboard surface to the inboard surface of the
25 outboard-side glass plate 1A with an intermediate film or layer 4
(made of polyvinyl butyral or the like), so that the optical rotation
layer 2 is located between the outboard-side glass plate 1A and the
inboard-side glass plate 1B in such a manner that the optical
rotation layer 2 is separate from the outboard-side surface of the
30 inboard-side glass plate 1B, as clearly shown in Fig. 1. The inboard-
side glass plate 1B defines thereinside a passenger compartment in
which a driver (operator) and/or a vehicle passenger reside. It will be
understood that a layer of the intermediate film 4 lies between the

optical rotation layer 2 and the inboard-side glass plate 1B. Such a temporarily bonded structure is then subjected to a usual autoclave treatment, thereby obtaining a laminated glass 5 used for the automotive vehicle front windshield glass W.

5 The above-discussed laminated glass 5 is used as the automotive vehicle windshield glass W and forms part of the head-up display system S. The head-up display system S includes a displaying device or liquid crystal display 6. The displaying device 6 generates a display light of information such as a driving 10 information or the like. For example, the liquid crystal display 6 has an axis (plane) of polarization inclined 45° rightward relative to a vertical axis on the image plate of the display 6. The second optical rotation layer 7 is attached or bonded on the front surface of the display 6 so as to rotate the plane of rotation of light from the display 15 6 by about 45° leftward, thereby transmitting S-wave having an axis (plane) of polarization inclined about 45° relative to the polarization axis on the image plane of the display 6, at Brewster's angle (θ = about 56°) to the front windshield glass W. The S-wave has a direction of electric field, perpendicular to the surface of the 20 inboard-side glass plate 1B.

With the thus arranged display system S, first display information or display light of information whose polarization axis (plane) is inclined about 45° rightward relative to the vertical axis on the image plate of the display 6 is output and incident on the 25 second optical rotation layer 7 so as to be optically rotated by about 45° leftward to form S-wave. This S-wave reaches the inboard-side glass 1B, in which a part of the display light is reflected on the light-transmittable reflection layer 3 and reaches an eye 8 of an operator or driver so that the display information is clearly 30 recognized by the operator.

Another part of the display light (S-wave) entering the laminated glass 5 without reflection reaches the first optical rotation layer 2 to be optically rotated into P-wave. Then, this P-wave

reaches and outgoes to the inboard surface of the outboard-side glass plate 1A at Brewster's angle, so that P-wave can be prevented from being reflected to the side of the eye 8 by the inboard surface of the outboard-side glass plate 1A. As a result, a whole amount of P-wave 5 outgoes to the outboard side of the glass plate 1A without being reflected toward the eye 8 of the operator.

It will be understood that the light-transmittable reflection layer 3 is not necessarily required since light can be reflected by the inboard surface of the inboard-side glass plate 1B; 10 however, an amount of light to be reflected to the side of the eye 8 will be reduced.

Hereinafter, constituents of the display system S of the present invention will be discussed in connection with the above embodiment.

15 While only the liquid crystal polymer represented by the above chemical formula has been described as being used as the first and second optical rotation layers 2, 7, the liquid crystal polymer as the material of the first and second rotation layers 27 will be discussed.

20 Each of the optical rotation (polarization-direction changing) layers 2, 7 are formed in the following manner: The liquid crystal polymer is coated on a transparent substrate (substrate film) such as a plastic film formed of, for example, polyethylene terephthalate (PET). Then a shearing force, an electric field, or a 25 magnetic field is applied to the liquid crystal polymer, and thereafter the liquid crystal polymer is subjected to heat-treatment and then cooling so that the orientation of the liquid crystal polymer is fixed. Thus, the optical rotation layer 2 is formed on the surface of the substrate film.

30 Otherwise, the optical rotation layer 2 is formed in the following manner: A oriented film is formed on a transparent substrate (substrate film). The oriented film is rubbing polyimide film, rubbing polyvinyl alcohol film, or a film formed by depositing

silicon oxide on the substrate. A liquid crystal polymer is coated on the oriented film, and then subjected to heat-treatment and then cooling so that the orientation of the liquid crystal polymer is fixed.

It will be understood that the liquid crystal polymer itself 5 may be used as the optical rotation layers 2, 7 without the transparent substrate, after its orientation is fixed in the above manner.

The optical rotation layers 2, 7 used in the display system S have a thickness ranging from 0.5 to 20 μm , and preferably 1 to 15 10 μm .

An optical rotation angle at which the plane of polarization of light is rotated or changed under the effect of the optical rotation layer can be regulated by controlling a content of optically active unit components in the liquid crystal polymer, a thickness of the 15 liquid crystal polymer, conditions of the heat-treatment for causing the liquid crystal polymer to exhibit a crystalline characteristics, and the like. The first optical rotation layer 2 has the optical rotation angle of about 90°. The second optical rotation layer 7 has an optical rotation angle of about 45°.

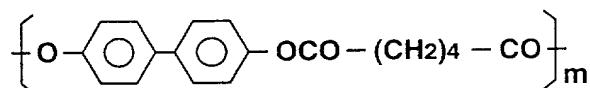
20 The liquid crystal polymer to be used as the optical rotation layer of the display system S is in twisted nematic orientation under a liquid crystal condition and is in a glassy state at a temperature lower than liquid crystal transition point thereof. Examples of the liquid crystal polymer are a main-chain type 25 polymer such as optically active polyester, polyamide, polycarbonate, and polyesterimide, and a side-chain type polymer such as optically active polyacrylate, polymethacrylate, polymalonate, and polysiloxane. Additionally, the liquid crystal polymer to be used as the optical rotation layer may be a polymer composition which is 30 prepared by adding optically active polymers to such main-chain type polymer or side-chain type polymer which is optically inactive.

Concrete examples of the liquid crystal polymer to be used as the optical rotation layer are polymers represented by the

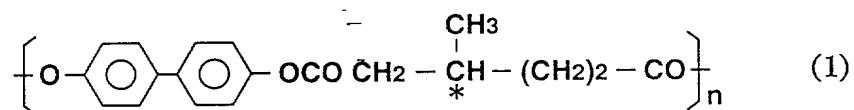
chemical formulae (1) to (7) discussed below. All these polymers have a glass transition point (temperature) ranging from 0 °C to 150 °C, and are in twisted nematic orientation at a temperature higher than the glass transition point and is in a glassy state at a temperature 5 lower than the glass transition point. The examples of the polymers are as follows:

A polymer represented by the following chemical formula (1):

10



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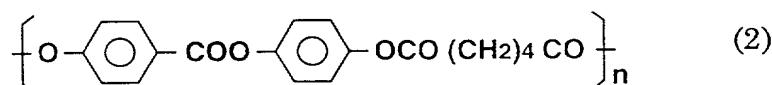
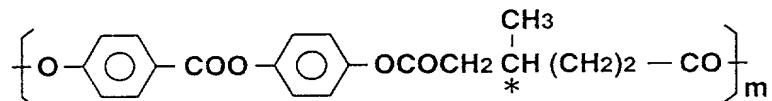


where $n/m = 99.9/0.1$ to $70/30$, preferably $99.8/0.2$ to $90/10$, more preferably $99.7/0.3$ to $95/5$; and a symbol * in the formula represents optically active carbon (this is common in the formulae shown below).

20

A polymer represented by the following chemical formula (2):

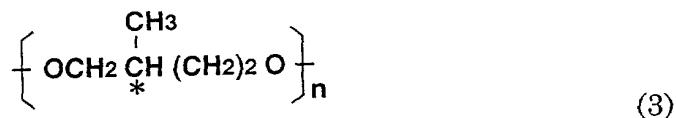
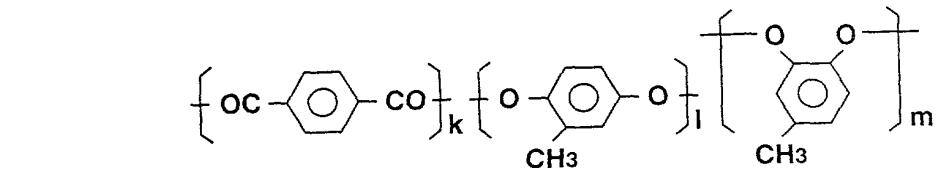
25



where $m/n = 0.1/99.9$ to $10/90$, preferably $0.3/99.7$ to $5/95$.

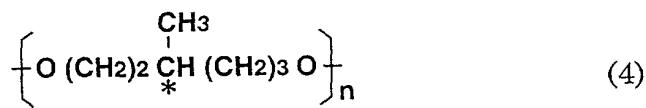
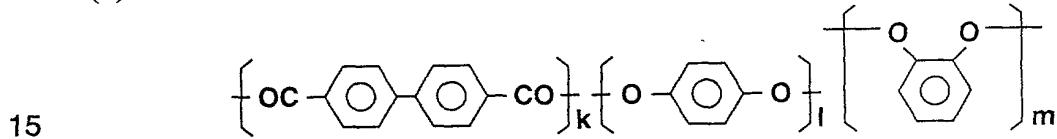
30

A polymer represented by the following chemical formula (3):



where $k = 1 + m + n$; $k/n = 99.9/0.1$ to $90/10$, preferably $99.7/0.3$ to 10 $95/5$; and $1/m = 5/95$ to $95/5$.

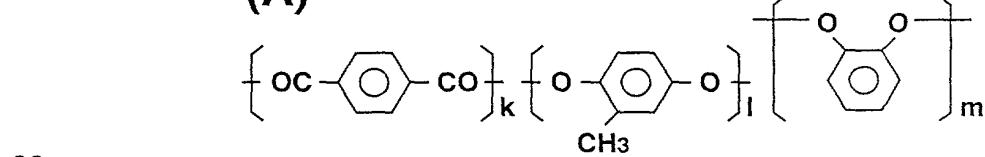
A polymer represented by the following chemical formula (4):



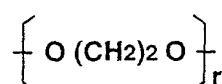
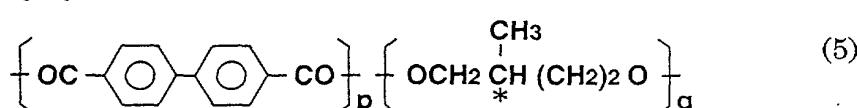
20 where $k = 1 + m + n$; $k/n = 99.9/0.1$ to $90/10$, preferably $99.7/0.3$ to $95/5$; and $1/m = 5/95$ to $95/5$.

A mixture represented by the following formulae (5), of a first polymer represented by a chemical formula (A) and a second 25 polymer represented by a chemical formula (B):

(A)



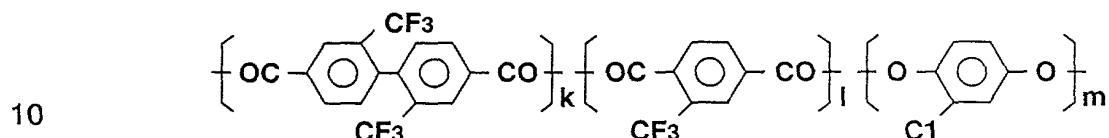
(B)



where a weight ratio (A)/(B) = 99.9/0.1 to 80/20, preferably 99.8/0.2 to 90/10, more preferably 99.7/0.3 to 95/5; k = 1 + m, l/m = 75/25 to 25/75; p = q + r; and q/r = 80/20 to 20/80.

5 A mixture represented by the following formulae (6) of a polymer represented by a chemical formula (A) and a compound (B):

(A)



(B) CHOLESTERYL BENZOATE

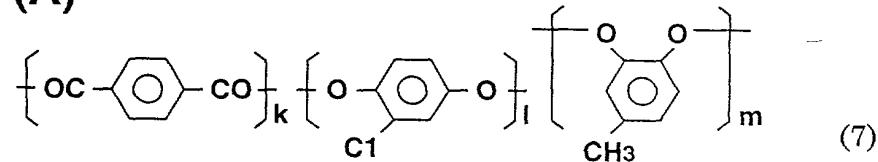
(6)

15 where a weight ratio (A)/(B) = 99.9/0.1 to 70/30, preferably 99.8/0.2 to 80/20, more preferably 99.7/0.3 to 90/10; m = k + 1; and k/l = 80/20 to 20/80.

A mixture represented by the following chemical formulae (7), of a first polymer represented by a chemical formula (A) and a second polymer represented by a chemical formula (B):

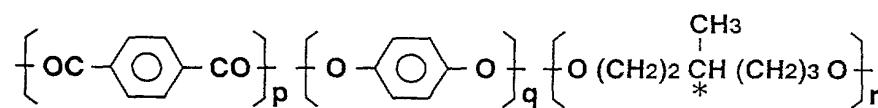
20

(A)



25

(B)



30

where a weight ratio (A)/(B) = 99.9/0.1 to 70/30, preferably 99.8/0.2 to 80/20, more preferably 99.7/0.3 to 90/10; K = 1 + m; l/m = 25/75 to 75/25; p = q + r; and q/r = 20/80 to 80/20.

The above polymers have an inherent viscosity relating to a molecular weight is preferably within a range of from 0.05 to 3.0 (dl/g), more preferably within a range of from 0.07 to 2.0 (dl/g), in which the inherent viscosity being measured at 30 °C by using a 5 variety of solvents such as tetrahydrofuran, acetone and a mixture solvent of phenol/tetrachloroethane (60/40). If the inherent viscosity is lower than 0.05, resultant liquid crystal polymer is lowered in strength. If the inherent viscosity is higher than 3.0, the viscosity of 10 a material during formation of liquid crystal becomes too high, thereby degrading formation of liquid crystal orientation and requires a long time for formation of liquid crystal orientation.

In the display system S, when the display light of information from the side of the liquid crystal display 6 is incident on the transparent plate or glass plate 1B at Brewster's angle, the 15 display light may be S-wave (S-polarized light) having a direction of electric field perpendicular to the surface (plane of incidence) of the glass plate, or P-wave (P-polarized light) having a direction of electric field parallel with the surface (plane of incidence) of the glass plate 1B; however, S-wave is preferable because reflection on 20 the outer-most or inboard-most layer can be effectively made so as to increase an amount of the light reflected toward the eye 8 as compared with P-wave.

The plane (axis) of polarization of the liquid crystal display is inclined about 45° relative to the vertical axis of the image plane of 25 the liquid crystal display, in which it may be inclined about 45° rightward or about 45° leftward. In case of being inclined 45° rightward, the display light of information from the liquid crystal display is converted into S-wave by using the second optical rotation layer 7 which rotates the plane of polarization about 45° leftward, so 30 as to be incident on the glass plate 1B. Otherwise, the display light of information from the liquid crystal display is converted into P-wave by using the second optical rotation layer 7 which rotates the

plane of polarization about 45° rightward, so as to be incident on the glass plate 1B.

In case of being inclined about 45° leftward, the display light of information from the liquid crystal display becomes S-wave 5 by using the second optical rotation layer 7 which rotates the plane of polarization about 45° rightward, so as to be incident on the glass plate 1B. Otherwise, the display light of information from the liquid crystal display becomes P-wave by using the second optical rotation layer 7 which rotates the plane of polarization about 45° leftward, so 10 as to be incident on the glass plate 1B.

It is preferable to use the light-transmittable reflection layer 3 to reflect the display light of information from the liquid crystal display 6 thereby to increase the amount of the display light to be reflected toward the eye 8 as compared with a case where the 15 display light is reflected on a surface or the inboard surface of the glass plate 1B. However, the display light may be reflected directly on a surface or the inboard surface of the glass plate 1B without using the light-transmittable reflection layer 3.

In case of using the light-transmittable reflection layer 3, 20 in order that the display light is incident on the glass plate 1B as S-wave, the layer 3 is to be provided on the inboard-most surface of the glass plate 1B on the side of the liquid crystal display 6. In order that the display light is incident on the glass plate 1B as P-wave, the light-transmittable reflection layer 3 is to be provided on the 25 outboard-most surface of the glass plate 1A which surface is on the opposite side of the liquid crystal display 6.

While the display system S of the embodiments has been shown and described as including one or two (inorganic) glass plates, it will be understood that the glass plates may be replaced with a 30 single transparent plate or two transparent plates, in which each transparent plate is made of a transparent organic glass plate such as a transparent plastic plate. Otherwise, the two transparent plates

may be an inorganic glass plate and an organic glass plate, respectively.

The display system S of the embodiments has been shown and described as the head-up display system including an 5 automotive vehicle front windshield glass, it will be understood that the display system S may include other window glasses of the automotive vehicle so as to form a combiner, or includes a single glass plate (separate from the windshield glass or window glass) so as to form a separate combiner. Additionally, the display system S 10 may includes architectural glass or a partition wall glass so as to display a variety of information.

In case that the display system S includes a vehicular (for example, automotive vehicle) windshield glass (laminated glass), it is preferable to bond the optical rotation layer 2 onto the inboard 15 surface of the outboard-side glass plate 1A from the view point of improving so-called impact and penetration resistance of the windshield glass. The impact resistance is improved because a part (in contact with the optical rotation layer 2) of the outboard-side glass cannot drop into the passenger compartment even when the 20 windshield glass is broken, though the part is low in bonding strength as compared with the other parts in contact with the intermediate film 4 made of polyvinyl butyral. Additionally, it is preferable to bond the optical rotation layer 2 onto the outboard surface of the inboard-side glass plate 1B from the view point of 25 improving durability of the optical rotation layer 2 because sun light reaches the optical rotation layer through the intermediate film (polyvinyl butyral) so that ultraviolet ray can be absorbed by the intermediate film to some extent.

The optical rotation layer 2 has been shown and described 30 as being formed of the liquid crystal polymer which is in twisted nematic orientation under liquid crystal condition and is in glassy state at a temperature lower than a liquid crystal transition point thereof. This is preferable from the view point of preventing double

image from being formed throughout a whole visible region. However, it will be appreciated that the above-type of the optical rotation layer may be replaced with other types of optical rotation films such as a transparent film having a birefringence, and a so-called $\lambda/2$ film or layer.

Fig. 2 illustrates a second embodiment of the display system S according to the present invention, similar to the first embodiment shown in Fig. 1. In this embodiment, the optical rotation layer 2 (capable of rotating the plane of polarization of light by about 90° to be incident thereon) formed in the same manner as in the first embodiment is removed from the substrate film and then bonded to the inboard surface of the outboard-side glass plate (transparent plate) 1A forming part of the front windshield glass W, with a tape-like adhesive (not shown). The light-transmittable reflection film or layer 3 is formed at a part of the outboard surface of the outboard-side glass plate (transparent plate) 1A forming part of the front windshield glass W, under deposition of a metal thin film formed of Al, Au, Ag, Cu or the like.

Thereafter, the inboard-side glass plate 1B is temporarily bonded at its outboard surface to the inboard surface of the outboard-side glass plate 1A with the intermediate film or layer 4 (made of polyvinyl butyral or the like), so that the optical rotation layer 2 is located between the outboard-side glass plate 1A and the inboard-side glass plate 1B in such a manner that the optical rotation layer 2 is separate from the outboard-side surface of the inboard-side glass plate 1B, as clearly shown in Fig. 2. The inboard-side glass plate 1B defines thereinside the passenger compartment in which the driver (operator) and/or the vehicle passenger reside. It will be understood that the layer of the intermediate film 4 lies between the optical rotation layer 2 and the inboard-side glass plate 1B. Such a temporarily bonded structure is then subjected to a usual autoclave treatment, thereby obtaining the laminated glass 5 used for the automotive vehicle front windshield glass W.

50 45 40 35 30 25 20 15 10 5 0

The above-discussed laminated glass 5 is used as the automotive vehicle windshield glass W and forms part of the head-up display system S. The head-up display system S includes the displaying device or liquid crystal display 6. The liquid crystal display 6 generates the display light of information such as the driving information or the like. For example, the liquid crystal display 6 has the axis (plane) of polarization inclined about 45° leftward relative to the vertical axis on the image plate of the display light from the display 6. The second optical rotation layer 7 is attached or bonded on the front surface of the display 6 so as to rotate the plane of rotation of light from the display 6 by about 45° leftward, thereby transmitting P-wave having an axis (plane) of polarization inclined about 45° relative to the polarization axis on the image plane of the display 6, at Brewster's angle (θ = about 56°) to the front windshield glass W. The P-wave has a direction of electric field, parallel with the surface of the inboard-side glass plate 1B.

With the thus arranged display system S, first the display light of information whose polarization axis (plane) is inclined about 45° leftward relative to the vertical axis on the image plane of the display 6 is output and incident on the second optical rotation layer 7 so as to be optically rotated by about 45° leftward to form P-wave. This P-wave reaches the inboard-side glass 1B, in which no reflection is made so as to allow a whole amount of the incident light or P-wave to income into the laminated glass 5. The P-wave reaches to and is rotated by the first optical rotation layer 2 by 90° so as to be converted into S-wave. Then, the S-wave reaches the outboard surface of the outboard-side glass plate 1A, upon which a part of the S-wave outgoes to the outside of outboard-side glass plate 1A while the other part is reflected by the light-transmittable reflection layer 3 and again passes through the first optical rotation layer 2 to be converted into P-wave. This P-wave reaches the inboard surface of the inboard-side glass plate 1B. At this time, the P-wave outcomes at

Brewster's angle through the inboard surface of the inboard-side glass plate 1B, so that no reflection is made here. As a result, a whole amount of the P-wave can outcome toward the eye 8 so that the display information can be clearly recognized by the operator.

5 It will be understood that the light-transmittable reflection layer 3 is not necessarily required since light can be reflected by the outboard surface of the outboard-side glass plate 1A; however, an amount of light to be reflected to the side of the eye 8 will be reduced.

10 Fig. 3 illustrates a third embodiment of the display system S according to the present invention, similar to the first embodiment shown in Fig. 1. In this embodiment, the optical rotation layer 7 (capable of rotating the plane of polarization of light by about 45° to be incident thereon) formed in the same manner as in the first 15 embodiment is removed from the substrate film and then bonded to the inboard surface of the outboard-side glass plate (transparent plate) 1A forming part of the front windshield glass W, with a tape-like adhesive (not shown). The light-transmittable reflection film or layer 3 is formed at a part of the inboard surface of the inboard-side 20 glass plate (transparent plate) 1B forming part of the front windshield glass W, under deposition of a metal thin film formed of Al, Au, Ag, Cu or the like.

Thereafter, the inboard-side glass plate 1B is temporarily bonded at its outboard surface to the inboard surface of the 25 outboard-side glass plate 1A with the intermediate film or layer 4 (made of polyvinyl butyral or the like), so that the optical rotation layer 7 is located between the outboard-side glass plate 1A and the inboard-side glass plate 1B in such a manner that the optical rotation layer 7 is separate from the outboard-side surface of the 30 inboard-side glass plate 1B, as clearly shown in Fig. 3. The inboard-side glass plate 1B defines thereinside the passenger compartment in which the driver (operator) and/or the vehicle passenger reside. It will be understood that the layer of the intermediate film 4 lies

between the optical rotation layer 2 and the inboard-side glass plate 1B. Such a temporarily bonded structure is then subjected to a usual autoclave treatment, thereby obtaining the laminated glass 5 used for the automotive vehicle front windshield glass W.

5 The above-discussed laminated glass 5 is used as the automotive vehicle windshield glass W and forms part of the head-up display system S. The head-up display system S includes the displaying device or liquid crystal display 6. The displaying device 6 generates the display light of information such as the driving 10 information or the like. In this embodiment, the liquid crystal display 6 is arranged to have the axis (plane) of polarization inclined about 45° rightward relative to the vertical axis on the image plate of the display 6, in which the display light from the display is incident on the laminated glass 5 at Brewster's angle (θ = about 56°).

15 With the thus arranged display system S, first the display light of information whose polarization axis (plane) is inclined about 45° rightward relative to the vertical axis on the image plate of the display 6 is output and incident as it is on the inboard-side glass plate 1B. A part of the display light reaching the glass plate 1B is 20 reflected on the surface of the light-transmittable reflection layer 3 and reaches the eye 8 of the operator or driver on the side of the liquid crystal display 6 so that the display information is clearly recognized by the operator. Another part of the display light entering the laminated glass 5 without reflection reaches the second 25 optical rotation layer 7 so that a generally whole amount of it is optically rotated by about 45° to form P-wave. Then, this P-wave reaches and outgoes to the inboard surface of the outboard-side glass plate 1A at Brewster's angle, so that P-wave can be prevented from being reflected to the side of the eye 8 by the inboard surface of the 30 outboard-side glass plate 1A. As a result, a whole amount of P-wave outgoes to the outboard side of the glass plate 1A without being reflected toward the eye 8 of the operator.

It will be understood that the light-transmittable reflection layer 3 is not necessarily required since light can be reflected by the inboard surface of the inboard-side glass plate 1B; however, an amount of light to be reflected to the side of the eye 8 will be reduced.

WHAT IS CLAIMED IS:

1. A display system comprising:
 - a transparent plate;
 - 5 a liquid crystal display for generating a display light of information, said display light having a plane of polarization inclined by an angle of about 45° relative to a vertical axis of an image plane of said liquid crystal display;
 - 10 a first optical rotation layer disposed to a first surface of said transparent plate, said optical rotation layer being adapted to receive the display light from said liquid crystal display and to optically rotate the plane of polarization of the display light by an angle of about 90°; and
 - 15 a second optical rotation layer disposed between the image plane of said liquid crystal display and a second surface of said transparent plate, said optical rotation layer being adapted to optically rotate the plane of polarization of the display light from liquid crystal display by an angle of about 45° and to allow S-polarized light to outgo toward said transparent plate at Brewster's angle, the S-polarized light being reflected on a side of the second 20 surface of said transparent plate to be directed toward an eye of an operator.
2. A display system as claimed in Claim 1, further comprising a light-transmittable reflection layer disposed on the 25 second surface of said transparent plate, S-polarized light from said second optical rotation layer being reflected on said light-transmittable reflection layer and directed toward the eye of the operator.
- 30 3. A display system comprising:
 - a transparent plate;
 - 35 a liquid crystal display for generating a display light of information, said display light having a plane of polarization

inclined by an angle of about 45° relative to a vertical axis of an image plane of said liquid crystal display;

5 a first optical rotation layer disposed to a second surface of said transparent plate, said optical rotation layer being adapted to optically rotate the plane of polarization of the display light incident thereon by an angle of about 90°, the display light from said first optical rotation layer being reflected on the second surface of said transparent plate and directed toward an eye of an operator; and

10 a second optical rotation layer disposed between the image plane of said liquid crystal display and a second surface of said transparent plate, said second optical rotation layer being adapted to optically rotate the plane of polarization of the display light from liquid crystal display by an angle of about 45° and to allow P-polarized light to outgo toward said first optical rotation layer at 15 Brewster's angle.

4. A display system as claimed in Claim 3, further comprising a light-transmittable reflection layer disposed on a first surface of said transparent plate, the display light passed through 20 said transparent plate being reflected on said light-transmittable reflection layer and directed toward the eye of the operator.

5. A display system comprising:

25 a transparent plate;

a liquid crystal display for generating a display light of information, said display light having a plane of polarization inclined by an angle of about 45° relative to a vertical axis of an image plane of said liquid crystal display, the display light being incident on a second surface of said transparent plate at Brewster's 30 angle and reflected on a side of the second surface of transparent plate to be directed to an eye of an operator; and

an optical rotation layer disposed to a first surface of said transparent plate, said optical rotation layer being adapted to

receive the display light from said liquid crystal display and to optically rotate the plane of polarization of the display light from said liquid crystal display by an angle of about 45° and to allow P-polarized light to outgo therefrom.

5

6. A display system as claimed in Claim 5, further comprising a light-transmittable reflection layer disposed on a second surface of said transparent plate, the display light from said liquid crystal display being reflected on said light-transmittable reflection layer and directed toward the eye of the operator.

ABSTRACT OF THE DISCLOSURE

A head-up display system for an automotive vehicle, comprising a transparent plate. A liquid crystal display is provided for generating a display light of information, in which the display light has a plane of polarization inclined by an angle of about 45° relative to a vertical axis of an image plane of the liquid crystal display. A first optical rotation layer is disposed to a first surface of the transparent plate. The optical rotation layer is adapted to receive the display light from the liquid crystal display and to optically rotate the plane of polarization of the display light by an angle of about 90°. A second optical rotation layer is disposed between the image plane of the liquid crystal display and a second surface of the transparent plate. The optical rotation layer is adapted to optically rotate the plane of polarization of the display light from liquid crystal display by an angle of about 45° and to allow S-polarized light to outgo toward the transparent plate at Brewster's an. The S-polarized light is reflected on a side of the second surface of the transparent plate to be directed toward an eye of an operator.

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25

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FIG.1

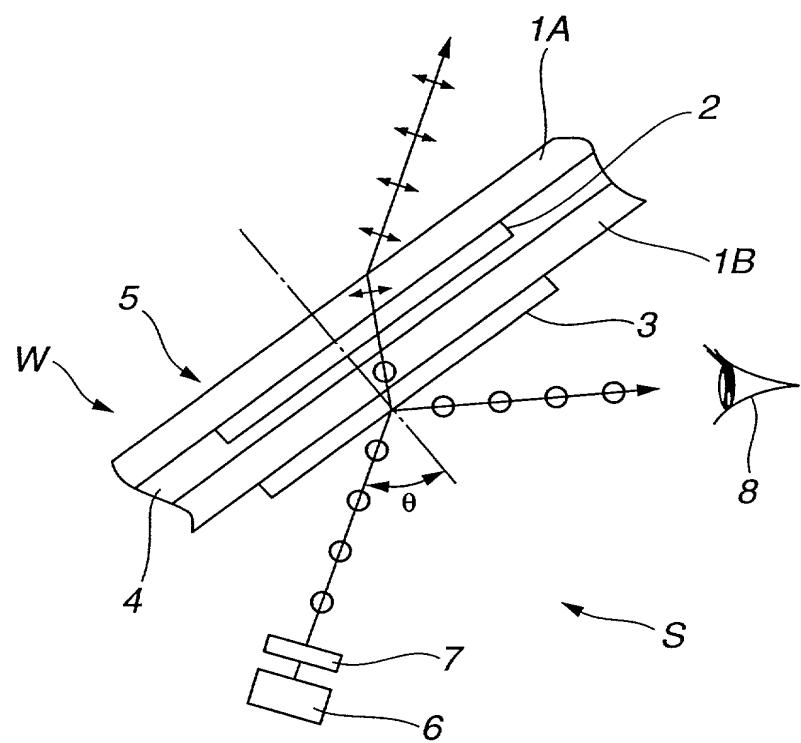


FIG.2

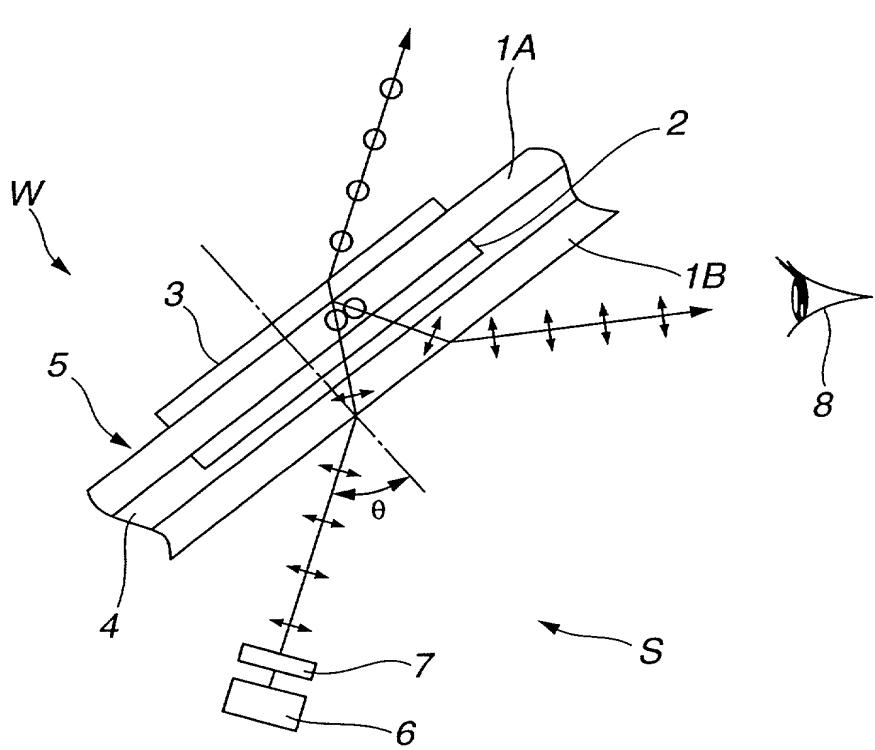
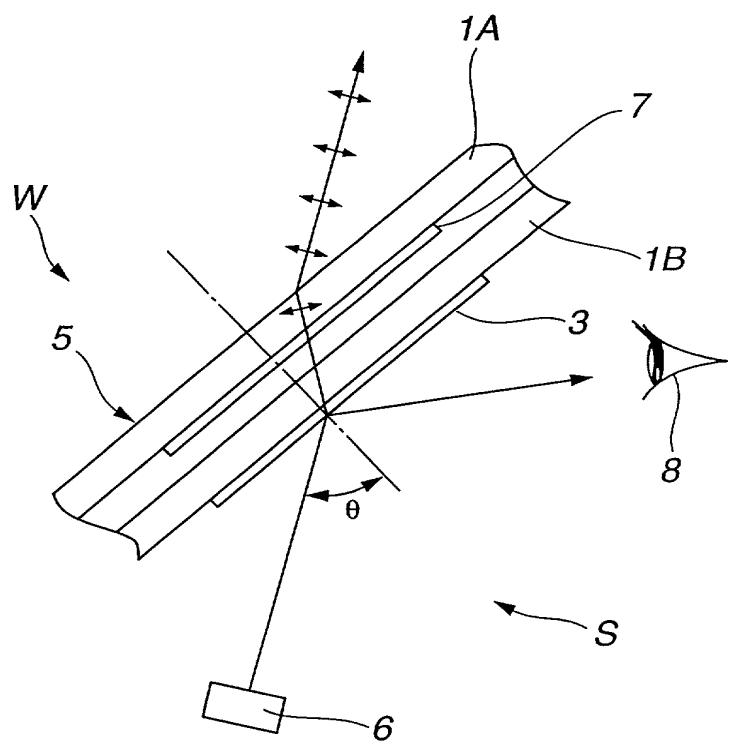


FIG.3



DECLARATION AND POWER OF ATTORNEY - PATENT APPLICATION

As a below named inventor, I hereby declare that my citizenship, postal address and residence are as stated below; that I verily believe I am the original, first and sole inventor (if only one inventor is named below) or a joint inventor (if plural inventors are named below) of the invention entitled:

DISPLAY SYSTEM

the specification of which

X is attached hereto, or

____ was filed on ____ as Application Serial No. ____ and

was amended on ____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose all information known to be material to patentability as defined in 37 CFR §1.56. I hereby claim foreign priority benefits under Title 35, United States Code §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)		Priority Claimed	
JP 10-372523 (Number)	Japan (Country)	28 Dec. 1998 (Day/Month/Year)	yes
JP 10-10032 (Number)	Japan (Country)	22 Jan. 1998 (Day/Month/Year)	no

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose all information known to be material to patentability as defined in 37 CFR §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	(Filing Date)	(Status)
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I hereby appoint as principal attorneys James F. McKeown, Reg. No. 25,406; Donald D. Evenson, Reg. No. 26,160; Gary R. Edwards, Reg. No. 31,824; Joseph D. Evans, Reg. No. 26,269; Herbert I. Cantor, Reg. No. 24,392, and Jeffrey D. Sanok, Reg. No. 32,169 to prosecute and transact all business in the Patent and Trademark Office connected with this application and any related United States and international applications. Please direct all communications to:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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